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Wind Turbine Syndrome – An appraisal

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This appraisal is based on a review of the material which has been on the web page www.windturbinesyndrome.com and on the digital version of paediatrician-ornithologist Dr Nina Pierpont's forthcoming self-published book "Wind Turbine Syndrome" (prepublication draft dated June 30, 2009).[1]

I am not a neurologist, and so my discussion will focus on the physics and acoustics addressed by Pierpont in her book. It will be shown that Pierpont's poor understanding of physics and acoustics has led her into errors which invalidate her discussions on neurological effects, at least in so far as the low levels of infrasound and low frequency noise from wind turbines are concerned.

1.0 Introduction. The book is easy to read and has nearly 150 references. On page 9 Pierpont states that her goal is "scientific precision." She interviewed a number of people who responded to a request she published online seeking individuals who claimed to be adversely affected by wind turbine noise, and lists the symptoms for ten families, giving data on 37 exposed persons. She groups the symptoms together as the Wind Turbine Syndrome of the title, and explains their origin through two hypotheses described by her as follows:

2.0 Hypothesis 1 - Book page 10.

> **"Wind Turbine Syndrome, I propose, is mediated by the vestibular system—by disturbed sensory input to eyes, inner ears, and stretch and pressure receptors in a variety of body locations. These feed back neurologically onto a person's sense of position and motion in space, which is in turn connected in multiple ways to brain functions as disparate as spatial memory and anxiety. Several lines of**

[1] The page numbers given in this appraisal are from the prepublication draft. They will not be the same as those in the printed book. The Book is published by K Selected Books. Dr. Pierpont and her husband, Calvin Martin, are two of the four editors of K Selected Books.

evidence suggest that the amplitude (power or intensity) of low frequency noise and vibration needed to create these effects may be even lower than the auditory threshold at the same low frequencies. Restating this, it appears that even low frequency noise or vibration too weak to hear can still stimulate the human vestibular system opening the door for the symptoms I call Wind Turbine Syndrome. I am happy to report, there is now direct experimental evidence of such vestibular sensitivity in normal humans."

3.0 Hypothesis 2 - Book page 42.

Note: VVVD is "visceral vibratory vestibular disturbance," which is a symptom Pierpont claims to have discovered, and claims is uniquely caused by wind turbines.

> **"With this background, I propose the following mechanism for VVVD. Air pressure fluctuations in the range of 4-8 Hz, which may be harmonics of the turbine blade-passing frequency, may resonate (amplify) in the chest and be felt as vibrations or quivering of the diaphragm with its attached abdominal organ mass (liver). Slower air pressure fluctuations, which could be the blade-passing frequencies themselves or a lower harmonic (1-2 Hz), would be felt as pulsations as opposed to the faster vibrations or quivering. (The vibrations or pressure fluctuations may also be occurring at different frequencies, without this particular resonance amplification.) The pressure fluctuations in the chest could disturb visceral receptors, such as large vessel or pulmonary baroreceptors or mediastinal stretch receptors which function as visceral graviceptors. These aberrant signals from the visceral graviceptors, not concordant with signals from the other parts of the motion-detecting system, have the potential to activate the integrated neural networks that link motion detection with somatic and autonomic outflow, emotional fear responses, and aversive learning."**

3.1 To summarise, Pierpont's thesis is that the low levels of infrasound and low frequency noise from wind turbines have a direct pathophysiological effect on the body, through the vestibular system (the system within the body that senses motion) and also by excitation of the airways and diaphragm to the viscera. Based on these hypotheses, Pierpont follows with a lengthy review of the neurology of vestibular disturbances and related matters. What she writes on neurology may or may not be good science, but appears irrelevant to noise produced by wind turbines, because her theory requires that wind turbine noise delivers orders of magnitude more energy to the listener than in reality, and because it posits impacts from low frequency sound that have never been observed from another source of similar level to the sound from wind turbines. We are then left only with the results of her telephone interviews, which will be referred to later.

4.0 The fundamental flaw in all of Dr. Pierpont's work is that she has a poor understanding of the fundamental physics of acoustics and vibration, which has hampered her work from the beginning, seriously limiting her ability to contribute in these areas. In common with many other lay people, she does not have an adequate understanding of acoustic levels, or of the pressures which lie behind decibels.[2]

5.0. Levels of infrasound and low frequency noise from wind turbines.

Pierpont (page 57) quotes van den Berg as giving wind turbine levels outside of a residence at a persistent complaint location as

1Hz	70 –100dB
10Hz	55 – 75dB
100Hz	50 –60dB

The levels at 1Hz are inaudible, and are within the range of naturally occurring infrasound (Bedard, 1998). We are exposed to infrasound in many of our activities. For example: when driving a car, especially with a window open; when jogging, where the change in level of the head produces infrasound at a frequency of a few hertz and level about 90dB. Even a child on a swing experiences infrasound at about 110db and 0.5Hz, depending on the length of the swing and change in height. If these levels of exposure are problematic, we should expect to see the effects in a wide swath of the exposed population.

Likewise, the levels at 10Hz are about 40 to 25 dB below the hearing threshold and will not be audible.

[2]For example, she tries, incorrectly, to manipulate decibels on page 46 of the book, whilst in the quotation on Hypothesis 1 above, an acoustician would not refer to "power or intensity" of a noise, but to pressure or intensity. There are other instances in the book and in her earlier work where she similarly misapplies acoustic concepts.

The levels at 100Hz are 20 – 30 dB above normal hearing threshold and will be audible externally. For comparison, 60 dB is sometimes identified as the sound level of a conversation at normal volume, at a distance of three feet.

Hayes (Hayes, 2006) carried out extensive measurements at three wind farms, where there had been complaints, finding similar, or lower, levels outside, and levels inside the house typically of

1Hz	around 70dB
10Hz	around 55dB
100Hz	around 30dB

The level of 30dB at 100Hz is a little above the average hearing threshold at this frequency.

6.0 Comments on Hypothesis 1-Vestibular Sensitivity to low-level, low-frequency sound.

Pierpont's statement that "several lines of evidence suggest" that low frequency sound at very low amplitude may cause physiological effects demands references, but none are given at that point. The only support which Pierpont gives is a paper by Todd and colleagues (Todd et al., 2008), which she claims as "direct experimental evidence of such vestibular sensitivity in normal humans." Her use of this paper is very puzzling, indeed alarming. The paper is entirely about sensing a vibration input to the mastoid area of the head, by both the normal hearing mechanism – the cochlea – and by the vestibular system. It does not deal with air conducted sound. Yet on her web page she wrote[3]

> **"In an article titled "Tuning and sensitivity of the human vestibular system to low-frequency vibration," three British scientists have demonstrated that the inner ear is "extremely sensitive" to extremely low levels of low frequency noise…**

[3] The following quotations were on the web page from early 2009 to mid August 2009, when they were removed after Dr. Neil Todd, primary author of the paper referred to by Pierpont, issued a statement to the effect that their work had been misinterpreted by Pierpont.

> **“This is precisely what Nina Pierpont has been talking about. This new research offers substantial support for her claim that *a perturbed vestibular apparatus* is one of the keys to explaining Wind Turbine Syndrome…”**

And then she quotes directly from the paper:

> **“The very low [noise] thresholds we found are remarkable as they suggest that humans possess a frog- or fish-like sensory mechanism which appears to exceed the cochlea for detection of substrate-borne low-frequency vibration and which until now has not been properly recognised…. A fundamental question is also raised as to the possible behavioral consequences … such a mechanism may have.”**

However, the word “[noise]” is not in the original, but had been added by Pierpont, as a comment, in order to be able to use this work to support her own unsubstantiated ideas.[4] Take out “[noise]” and it is very clear that the paper describes an experiment on vibration transmission through the skull. And of course, wearers of bone conduction hearing aids receive vibration inputs to their vestibular systems, at levels well above the cochlear and vestibular thresholds, and are not known to exhibit vestibular disturbance.

This fundamental misunderstanding of the difference between air conducted sound and a direct vibrational input is a cause for concern. It is certainly not the “scientific precision” which she claims for herself. There are further references in the book to the Todd paper in which she incorrectly, and persistently, couples sound with the original references to vibration. Does Pierpont understand the difference between noise and vibration? Although she has a poor understanding of acoustic magnitudes and their significance, it is difficult to believe that, after five years of campaigning against wind turbines,[5] she has not yet grasped this difference. However, the manner in which she has used Todd’s paper serves only to cast doubt on her scientific reliability.

7.0 Comments on Hypothesis 2 (“Body Resonance”).

[4] Pierpont has made similar additions, in other connections, to quotations from original authors.
[5] She started as a NIMBY, when wind turbines were proposed near to her home town of Malone NY.

Her hypothesis of movements of the viscera due to sound in the range of 1-2Hz and 4-8Hz is supported by reference to publications on “body resonances.” Again, she badly misunderstands the underlying physics. For example, on page 23 of the book we find

> **“All parts of the body (and indeed all objects) have specific resonance frequencies, meaning that particular frequencies or wavelengths of sound will be amplified in that body part. If the wavelength of a sound or its harmonic matches the dimensions of a room, it may set up standing waves in the room with places where the intersecting, reverberating sound waves reinforce each other. Resonance also occurs inside airfilled body cavities such as the lungs, trachea, pharynx, middle ear, mastoid, and gastrointestinal tract.”**

That is correct as far as it goes - except that small body spaces do not resonate at the long wavelength (low frequency) acoustic excitation, which she states cause the adverse effects. Indications are that the resonant frequency for sound transmission through the system comprising the mouth, the lungs, and the external chest wall is much higher in reality—as high as 200Hz—a frequency far above the low frequency noise assumed by Dr. Pierpont (Royston T J et al., 2002).

Other references which Pierpont gives to support her thesis are mainly from the investigations for the 1960s – 1970s space program, when subjects were exposed to very high infrasonic levels of 120 – 130dB, levels far beyond those produced by wind turbines. These exposures, which had little effect on the subjects, are not relevant to the sound levels from wind turbines.

The references she gives on page 23 to support Hypothesis 2, all relate to mechanical excitation of the body. That is, vibration input to the feet or seat or whole-body mechanical oscillation, for example, like a massaging chair or vibrating platform. Mechanical excitation, either vertical or horizontal, does not excite the same set of resonances as are driven by low frequency sound, because sound has a uniform compressive effect, while mechanical excitation is a longitudinal force. These references do not support Hypothesis 2.

References to excitation of the body by sound are given on page 42, with two papers from Takahashi and colleagues, on forehead vibration in high sound levels (Takahashi et al., 2005)(Takahashi et al., 1999). These also do not support Hypothesis 2. If Pierpont had read the papers more carefully, she would have found that internal head vibration (background vibration) masked responses of the head to low frequency sound below 20Hz, even when using a high stimulus of 110dB. This is far in excess of wind turbine levels and leads us to the ultimate failure of Pierpont's second hypothesis.

8.0 Internal body noise and vibration. The body is inherently a very noisy system at low frequencies. My own measurements on body vibration resulting from external low frequency noise showed that the inherent chest vibration was similar to that from excitation by an external sound level of 80dB at the chest resonant frequency, which was typically around 50Hz (Leventhall, 2006). Unlike the 200Hz resonance described above, this resonance was a structural resonance of the rib cage, and did not involve the lungs or other body cavities.

Internally generated body sounds may be detected by a microphone supported a few millimetres above the body surface, and indeed, the human diaphragm itself, which Pierpont depends on for transmission of wind turbine infrasound to the viscera, vibrates during its contraction, so radiating sound and vibration within the body. As stated in (Bellemare and Poirier, 2005)

> **"Like other skeletal muscles, the diaphragm vibrates laterally during the build-up of tension. These vibrations or sounds can be recorded with microphones or accelerometers positioned over the lower chest wall in the zone of apposition of the diaphragm with the rib cage."**

Pierpont's use of her stethoscope will have shown her that the body also contains a strong source of infrasound, working in the region 1Hz to 2Hz, which is one of the problem regions she suggests from wind turbines (Hypothesis 2). I am referring to the heart.

Any internal effect from the low levels of infrasound from wind turbines, say, 55-75dB at 10Hz, produce a much lower internal body vibration than that which already exists within the body, and will not be sensed by the body. It is interesting to note that a pressure of 74dB exerts equivalent pressure on the skin to that of a layer of water which is one hundredth of a millimetre thick (10^{-2}mm), lying over the skin. Skin thickness varies over the body, but is typically 1mm. (10^{-2}mm is similar to about five ten-thousandths of an inch.)

Again, Pierpont misunderstands the energy transmitted by sound to the body. Simple calculations shows that, if a system of the weight and area of the diaphragm and its attached liver are exposed to a level of 74dB for 50ms, which is one quarter cycle at 5Hz, the resulting displacement is only about five microns (5×10^{-6}m). Again, Pierpont's second hypothesis does not stand up to scrutiny.

The conclusion must be that, whatever Pierpont wishes to believe, infrasound and low frequency noise from wind turbines will not directly affect the body because the levels are too low and the body is full of low frequency masking sources. Both her hypotheses fail. The appropriate place for them is on the internet, along with other self published, alarmist infrasound material.

We are then left with the results of her case study interviews.

9. Case studies. Several years ago Pierpont put out a general call, repeated internationally on objector web pages, for anyone who thought that their health had been affected by wind turbines, to contact her for a telephone interview. She does not give details of the response. One of Pierpont's selection criteria was that a "before – during – after" exposure pattern was preferred, which meant that the interviewees will have moved away from the turbines. That is, they were the ones most severely affected and were a small selection from the people who might be bothered by wind turbine noise.

9.1 Results of interviews. Following the interviews, Pierpont defined the symptoms of the Wind Turbine Syndrome as:

> **"….sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and**

memory, and panic episodes associated with sensations of internal pulsation or quivering when awake or asleep." (Book page 18)

I am happy to accept these symptoms, as they have been known to me for many years as the symptoms of extreme psychological stress from environmental noise, particularly low frequency noise. The symptoms have been published before (Møller and Lydolf, 2002; Nagai et al., 1989).

9.2 Prior knowledge of these symptoms. Anybody who is fully experienced in environmental noise problems, particularly at "street level," will be familiar with the extreme responses to otherwise unobjectionable levels of sound which occur in a very small number of people. These responses occur for both higher frequency and low frequency noise. However, as environmental noise control criteria are A-weighted, they tend to under-rate potentially problematic low frequency environmental noise. This has led low frequency problems to be left to continue, whilst higher frequency problems are fixed more quickly. As a result, where genuine low frequency noise problems have occurred, their continuance leads to the development of undue stress in those affected. There is also a body of very stressful, unsolvable noise problems, described as "low frequency" by those affected, where detailed investigations cannot discover a specific noise source. These are sometimes called "Hum" problems and there is an Internet group devoted to them. The HUM FORUM. http://tech.groups.yahoo.com/group/humforum/

The paper by Nagai, referred to above, describes effects of rattles on residents in lightweight Japanese buildings. For example, rattling of windows, doors, etc. The rattles were caused by infrasound generated by traffic on an elevated highway. The infrasound, at about 80dB and 8Hz, was below perception level, but caused rattles, which disturbed residents. The rattle is at high frequencies, and produced the same symptoms as those found by Pierpont. Nagai had 909 subjects, whose complaints included:

> Irritating (62.4%), Headache (57.6 %), Heaviness in the head (52.8%), Pain in arms or legs (52.4%), Insomnia (47.6%), Confusion of thinking (42.6%) Vertigo (40.5%), Ringing in ears (29.6%), Palpitation (22.8%), Nausea or Vomiting (19.3%), Pressure on ears (17.9%), Hypertension (17.6%)

Nagai et al do speculate that long-term exposure to the noise might lead to increased sensitivity to the infrasonic element, but give no evidence for this effect at levels below the perception threshold.

The paper by Møller and Lydolf describes a survey conducted amongst 198 persons, who described themselves as low frequency noise sufferers. Some of these may have been stressed "Hum sufferers." The results on subjective effects were:

> Insomnia (67.5%), Lack of concentration (67%), Headaches (40.1%), Palpitation (41.1%), Dizziness (29.4%), Others (39.1%).

For a follow-up paper (Pedersen et al., 2008), 21 of the complainants from the Møller and Lydolf study were selected randomly for detailed investigations. This work concluded that seven of the complainants were annoyed by a physical sound in the 20 – 180Hz range. Six had low frequency tinnitus, perceived as between 40 and 100Hz. The remaining eight could not be classified. In no cases was infrasound a problem.

My own experience of helping those with noise problems, extending over about 40 years, has led me to the following list of symptoms (Leventhall, 2002)

> distraction; dizziness; eye strain; fatigue; feeling vibration; headache; insomnia; muscle spasms; nausea; nose bleeds; palpitations; pressure in the ears or head; skin burns; stress; tension etc.

9.3 Comparison of symptoms. The similarity of subjective effects found by Pierpont to those of Nagai at al, Møller and Lydolf and myself, demonstrates that what Pierpont describes is effects of annoyance by noise – a stress effect, not the direct physiological effect which she claims, as it has been shown above that these claims are without substance. What Pierpont describes are simply the well known effects of persistent, unwanted noise, and use of the words "Wind Turbine Syndrome" should be discontinued, in order to avoid confusion.

However, Pierpont has made one genuine contribution to the science of environmental noise, by showing that a proportion of those affected have underlying medical conditions, which act to increase their susceptibility. This is the only part of her book which merits further publication as original work.

10. Conclusions. Pierpont has failed to substantiate her hypotheses. These hypotheses lack credibility and do not appear to have any scientific basis. Pierpont has clearly misunderstood much of the acoustic material which she refers to.

The so called “wind turbine syndrome” cannot be distinguished from the stress effects from a persistent and unwanted sound. These are experienced by a small proportion of the population and have been well known for some time.

The final conclusion must be that Pierpont has misled both herself and her followers, but she can have the last word, as used by her in criticism of others:

> **Let me be emphatic.** ***You can’t start with an implausible hypothesis or a flawed data set and get a result that means anything.*** **(Book page 170)**

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